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ANNUAL REPORT

NETWORK FOR MEASURING RADIATIVELY ACTIVE GAS FLUX IN MANAGED BOREAL, TEMPERATE, AND TROPICAL SEMIARID GRASSLANDS

FAIRBANKS, AK

V.L. Cochran

Two gas chromatographs (one with an ECD detector and one with a FID detector) and 25 gas flux chambers have been obtained to measure N_2O and CH_4 at two sites near Fairbanks. One site has been in brome grass hay which has received 90 kg N ha^{-1} yr^{1} for about 8 years. The other site has been in brome grass for an unknown length of time, but has never been fertilized or cropped. Plots were established at each site to compare the effect of urea fertilizer on N_2O and CH_4 flus with that receiving no N fertilizer. At each site, six replications of each fertilizer treatment were incorporated into the experimental design. The base rings for the gas flux chambers were installed during the summer, but the gas chromatographs did not arrive in time for use during the 1991 growing season.

Data collection will begin as soon as the snow melts in the spring (late April). Gas flux will be measured during spring thaw with samples collected during early afternoon on alternate days (more frequently on selected days). After the soil thaws, urea solution will be hand applied to the base rings in those plots designated to be fertilized at an equivalent rate of 90 kg N ha^{-1}. Dry urea will be broadcast to the rest of the plot. Thermocouples will be installed at 2, 5, 10, and 15 cm for soil temperature measurements. Gas flux measurements will continue until the soil freezes in the fall (about the middle of October). Other planned measurements include: soil water, heat flux, and gas diffusion. There is an official weather station near the site which will monitor ambient air temperature and precipitation.

OTHER GLOBAL CHANGE STUDIES BEING CONDUCTED AT FAIRBANKS

Energy Balance in native forest and agricultural land in the subarctic.

A comparison of energy balance between native spruce forest and agricultural land was started in 1991. The necessary instruments to measure net radiation, soil heat flux, heat storage, water balance, and latent and sensible heat of these two management systems were installed during the summer. Two sites are being used. One is located near Fairbanks, AK. The other is located near Delta Junction, AK. Data has been collected over the winter and will continue throughout the year for two or more years.

Principal investigator: Brenton Sharratt

Response of high latitude crops and weeds to increased atmospheric CO_2.

The response of high latitude adapted crop and weed plants to increased levels of CO_2 will be studied using growth chambers and root zone temperature chambers. Interactions of CO_2 levels with temperature, day length, and soil water potentials will also be studied. Plant responses to be measured are: vegetative and reproductive development; water-use and light-use efficiencies; and canopy resistances. The studies will start as soon as the new growth chambers are operational.

Principal investigator: Jeffery Conn

12 February 1992

Report of 1991 progress in determination of:

XYLEM POTENTIAL MEASUREMENTS IN COTTON UNDER OPTIMAL AND LIMITING LEVELS OF WATER IN A FREE-AIR CO_2-ENRICHED ENVIRONMENT

B. A. Kimball, U. S. Water Conservation Laboratory,
N. C. Bhattacharya, and J. W. Radin, Western Cotton Research Laboratory
USDA, Agricultural Research Service
Phoenix, Arizona

Cotton was planted in a field with an underground drip irrigation system at the University of Arizona's Maricopa Agricultural Center on 16 April 1991. Apparatus was quickly installed to enrich the air in four replicate 22-m-dia plots to 550 ppmv of CO_2 as part of the FACE (free-air CO_2 enrichment) project. Similar control plots at ambient CO_2 ("amb") were also established. Then after an initial stand establishment period of about 1 month, a water stress ("dry") irrigation treatment (2/3 of "well-watered") was imposed in half of each of the main CO_2 plots, with the other halves receiving adequate ("wet") water.

Xylem potentials and leaf transpiration rates were measured on selected days in July, August, and September, 1991, using a pressure bomb and a Li-Cor steady-state porometer, respectively. The youngest fully-expanded leaves (fourth or fifth) of 8-10 plants were selected from each plot for measurement at each time.

Leaf water potentials at pre-dawn were near -1.1 MPa and did not change much regardless of CO_2 concentration or irrigation level throughout the season. In spite of the large difference in irrigation levels, the plants from the wet plots in both FACE and amb treatments had only slightly higher (lessb negative) water potentials than those from the dry plots, with the differences ranging from -0.25 to -0.30 MPa. This is because rather subtle differences in plant water status apparently cause plants the plants to adjust their size to accommodate the supply of water. The plants from the dry plots were smaller and had a smaller water requirement, so that at any particular time the absolute values of the xylem potentials were not much different.

But responses to CO_2 are of most interest to this project. In early August, there was little effect of CO_2, but progressively through August and into September, midday leaf water potentials of the control plots became drier than those of the FACE plots by about 3 MPa. Differences in leaf transpiration rates were minor, except on 21 August when rates from the FACE plots were about 10% lower than those of the control plots for most of the day.

Because of the changes of plant size with subtle changes in xylem potential, as discussed above, xylem potential is not a particularly good parameter for characterizing the overall water status of a crop. Nevertheless, these data should be useful for characterizing any effects of the CO_2 or irrigation treatments on the hydraulic properties of the cotton plants. Complementary measurements of stem-flow rates were made for most of the growing season by Dr. William Dugas, Texas A&M University, Temple, TX. Analyses of his data are progressing, and it is planned to combine his flow data with these potential data to calculate plant hydraulic conductivities.

CARBON ISOTOPES IN FACE COTTON SOILS-1991

Steven W. Leavitt, University of Arizona and
Eldor Paul, Michigan State University

On a global basis, soils represent an immense pool of carbon, but there has been much uncertainty about the fate of this carbon reservoir under future possible greenhouse conditions. For different conditions, it is hypothesized that soil carbon may become a sink or a source of atmospheric carbon dioxide. Field experiments to examine these hypotheses are necessarily difficult because even large changes in carbon storage on a field-size level may produce only very minor changes in soil organic carbon content that are difficult to measure with standard gravimetric techniques for total-carbon content measurements, which may be too coarse for resolution of the expected small changes. The FACE experiments being conducted by the USDA and DOE offer a unique opportunity to test the application of isotopic tracers to resolve the source-sink question. Specifically, the tank CO_2 used in the experiments to enrich the air above the FACE fields imparts a very distinctive isotopic signal to the air, which in turn is taken up by the cotton. The signal has dual isotopic qualities: its stable isotopic composition ($\delta^{13}C$ which reflects the $^{13}C/^{12}C$ ratio) is markedly enriched in ^{12}C relative to ambient air, and its radiocarbon concentration is effectively zero (it is devoid of ^{14}C). Soil fractions can then be measured to see if these isotopic signals are being incorporated into the soil, indicating enhanced organic accumulation in the soils.

Our plant analyses have established that the isotopic characteristics of air above the FACE fields are being incorporated by the plants. While the control (ambient) cotton plants have a radiocarbon content of 113pMC (percent modern carbon) and a $\delta^{13}C$ value of -28‰, the FACE cotton plants have a ^{14}C content of 71pMC and a $\delta^{13}C$ of -40‰. Early bulk soil stable-carbon isotope analyses of soils collected just prior to the 1991 growing season showed the carbon in the FACE soils was about 8‰ isotopically lighter (^{12}C-enriched) than the control soils. This is a signature acquired from the previous FACE growing seasons (1989 and 1990), but these "bulk" soils included plant fragments and not just soil organic carbon. For that reason, we are physically removing plant fragments via density separation, and then picking any remaining plant fragments from the soil under magnification. Ideally, these soils then contain only "total organic soil carbon" which we analyze directly, and which we can also fractionate into 6N HCL soluble and insoluble fractions, representing the more mobile and more recalcitrant pools of organic carbon, respectively. These analyses are ongoing, but preliminary results seem to suggest little stable-carbon isotopic difference between FACE and Control total organic carbon. Differences are seen, however, in the isotopic composition of the residual fine materials picked from the soils. Many more stable isotope and radiocarbon measurements are planned to quantify these relationships, including some microbial digestion experiments to determine relative resistance of soil organic components.

Additional measurements of stable-carbon isotope composition of cellulose of sorghum and sudan grass are being conducted in conjunction with the research of Dr. Hyrum Johnson for water-use efficiency studies and Dr. Danny Akin for studies on plant digestibility to animals.

ANNUAL REPORT

CARBON DIOXIDE PRODUCTION, DISTRIBUTION AND TRANSPORT IN SOIL

RIVERSIDE, CA

D.L. Suarez

Knowledge of the carbon dioxide concentration in the unsaturated zone is essential for simulating prediction of unsaturated zone chemistry and ground water recharge as well as for quantifying carbon source/sink terms and global CO_2 mass balance. Available carbon dioxide simulation models are based on regression relationships which are generally site specific. We developed a generalized predictive model based on process oriented relationships. The model includes, one dimensional water flow utilizing the Richard's and CD equations, respectively as well as heat flow and a CO_2 production model. The transport phenomena considered are convection and dispersion in the liquid phase and convection and diffusion in the gas phase. The gas transport equation includes provision for production of carbon dioxide and uptake of CO_2 by plant roots in connection with root water uptake. The CO_2 production model considers both microbial and root respiration which is dependent on water content, growth (utilizing the heat unit concept), and plant and soil characteristics (including optimum heat flow) is included, since some gas transport parameters, partitioning coefficients and production parameters are strongly temperature dependent. The resulting set of partial differential equations is solved using the finite element and finite difference methods. Input requirements include soil hydraulic characteristics, depth of impermeable layer, water applied, daily air max and min temperature, planting date, optimum plant productivity at 20 C (depends on plant type and CO_2 incentration in the atmosphere). The root distribution with depth can be input or generated by the model.

The developed model was utilized for a sensitivity analysis of various input and model generated parameters. Soil water content exerted the major influence on soil concentrations and flux to the atmosphere. The model was also evaluated by comparison of model simulations to 2 distinct field data sets. An experiment was conducted in Riverside, CA growing corn and utilizing high frequency irrigation to maintain an almost constant water content through most of the soil profile. The model simulation provided an adequate fit to the data with some underprediction, primarily in the early part of the experiment. This underprediction is attributed to an initial flush of

microbial production upon wetting a previously dry soil. An additional data set from the literature was utilized from the south-central US with wheat growth under nonirrigated conditions. The data provided both CO_2 concentrations with depth and time as well as measurements of flux to the atmosphere, under conditions of varying water content. The simulation provided an excellent fit to the data using only rooting distribution (which was unknown) as a fitting parameter.

PREDICTION OF LONG TERM CHANGES IN CARBON STORAGE AND PRODUCTIVITY OF U.S. SOILS AS AFFECTED BY CHANGES IN CLIMATE AND MANAGEMENT

CRIS Project 5402-11000-002-00D

Vernon Cole, Marv Shaffer and Jon Hanson

Progress Report 6/91 to 12/91

Shaffer:

Work progressed on the development of a comprehensive simulation model for the release and absorption of greenhouse gases by soils. The existing NTRM-2D model which includes provision for water, heat, and solute fluxes in 2-dimensions was refined for use on personal computers, and studied for inclusion of gas transport and reaction submodels. The literature was reviewed to identify potential gas transport models suitable for use within the context of the NTRM-2D model. Field data, including climate, topographic features, management practices and soil properties taken from a shortgrass steppe and a long-term cropping systems study in Colorado, were obtained to further improve the sub-components of the NTRM-2D model and provide a historical database for the gas transport model being developed. An updated version of the RZWQM carbon and nitrogen transformation model (OMNI) was developed that includes provision for greenhouse gas absorption from and release to the soil atmosphere. This model will be included in NTRM-2D along with a convective and diffusive gas transport submodel. A prototype soil-gas probe and field soil-gas sampling techniques are being developed for a better handle on the spatial variability encountered in soil-gas measurements, i.e. along and across the crop rows and along the vertical soil profile. An extensive field sampling program will be initiated in 1992, to collect data on CO_2, CH_4, and N_2O levels in agricultural soils along with appropriate soil properties suitable for use in model development and testing. (In cooperation with Romel Lapitan, C.V. Cole, J. Hanson, and A. Mosier).

Hanson:

The SPUR model was used to investigate the effect of predicted global climate change on livestock production within the U.S. Doubling of CO2 alone caused only slight increases of plant production, but when CO2 doubling was coupled with changes in precipitation and temperature, plant production increased significantly. Generally, both plant and animal production responded positively to climate change for the northern latitudes. However, higher production did tend to reduce the soil organic matter, increasing the chance for system degradation. Sustainability of long-term agriculture is necessary for a stable agricultural economy within the United States. Therefore, we must consider not only short-term economic trends, but also long-term ecological stability.

Cole:

The CENTURY model was modified to schedule a sequence of management events in a variety of cropping systems. A preprocessor called *event100* was written to schedule management events, the growth of different crops in rotation and to control the overall execution of the CENTURY model. The management events and crop growth controls which can be implemented by *event100* are crop type, planting and harvest months, first and last month of growth (for grassland or perennial crops), senescence month, cultivation, fertilizer addition, irrigation, addition of organic matter (straw or manure), grazing, fire and erosion. Schedules with different sequences can be appended in *event100* and run in succession in the CENTURY model. For example, a series of historical farm practices such as breaking of the native sod in 1920, a wheat-fallow rotation with plow cultivation and straw removal until 1940, wheat-fallow with stubble-mulch management until 1980, followed by wheat-sorghum-fallow can be scheduled. For grain crops a harvest index based on a genetic maximum and moisture stress in the two months prior to harvest is calculated. The crop harvest routine also allows for the harvest of roots, hay crops or straw removal after a grain crop. A revision of the decomposition submodel including an additional suite of pools for microbial biomass in surface litter is currently being implemented with the new version of CENTURY.

Flach:

A study of relationships between precipitation and wheat yields for the major wheat growing counties of Colorado for the years 1929 to 1989 was completed using a spreadsheet adaptation of Thornthwaite's water balance model. Corrected monthly temperature data were generated from NOAA records and relevant statistical analyses were performed. The model accounted well for differences in average yields between counties but annual predictions suffered from uncertainties whether precipitation events toward the end of the growing season influenced yields for the year in question. Literature on historic changes in land use and estimates on CO_2 release to the atmosphere that can be attributed to these changes was reviewed and major research issues were identified. Results of these studies were presented to the ARS Global Change Research Planning Workshop, Beltsville, MD, 3/20 - 3/22, 1991. The literature on the effect of conservation tillage on soil organic matter content was reviewed and statistical evaluation of available data was completed.

Organic Matter Workshop:

A Synthesis Workshop: Advances in Soil Organic Matter Studies: Global Change Issues was conducted in September 1991 at Pingree Park. A series of twelve papers was presented dealing with recent developments in concepts and methodologies in studies of soil organic matter formation and turnover. The focus of these reviews was the relevance to issues of global change resulting from shifts in land use and management as well as potential climatic shifts. These papers are currently under review and will be submitted jointly to a peer reviewed journal with wide exposure to the scientific community.

Authors include David Jenkinson (Rothamstead), Hans van Veen (Wageningen), Keith Paustian and Eldor Paul (Michigan State) Bill Parton and Ted Elliott (CSU-NREL), Phillip Sollins and Peter Homann (Oregon State), George Wagner (Univ. of Missouri), David Schimel (UCAR-CSMP), Susan Trombore (Lawrence Livermore Labs), Edward Gregorich (Ag Canada, Ottawa) and Vernon Cole (ARS).

Publications:

Baker, B.B. and J.D. Hanson. 1991. A management tool for rangeland systems. Pages 107-114 in: J.D. Hanson, M.J. Shaffer, D.A. Ball, and C.V. Cole (eds.), Sustainable Agriculture for the Great Plains, Symposium Proceedings. USDA, ARS, ARS-89, 255 pp.

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Hanson, J.D. 1991. Integration of the rectangular hyperbola for estimates of daily net photosynthesis. Ecological Modelling 58:209-216

CENTURY Model Revision:

The following work was conducted in collaboration with the Natural Resource Ecology Laboratory, Colorado State University under Specific Cooperative Agreement 54-5402-1-118 **Analysis of Changes in Soil Carbon Balance.**

The CENTURY soil organic matter simulation model (Parton *et al*, 1987; Parton *et al*, 1988) was originally developed for grasslands and wheat/fallow cropping systems typical of the semi-arid Great Plains (Parton *et al*, 1988). The model is being revised to include the capability of handling different crops in rotation in different geographical regions. Modifications needed to model crop rotations are 1) to schedule a sequence of management events, such as cultivation, planting and harvest over a number of years and 2) to simulate the growth and nutrient uptake of a variety of crops.

The model was modified by Laura Harding and Alister Metherell by the addition of a preprocessor called *event100* to schedule management events, the growth of different crops and to control the overall execution of the CENTURY model. The management events and crop growth controls which can be implemented by *event100* are crop type, planting and harvest months, first and last month of growth (for grassland or perennial crops), senescence month, cultivation, fertiliser addition, irrigation, addition of organic matter

(straw or manure), grazing, fire and erosion. Information pertaining to various crops and management practices is contained in a series of *.100* data files. A data manager, *file100*, can be used to update values in these parameter files or to create new options.

The management events and crop growth controls which can be implemented by *event100* are crop type, planting and harvest months, first and last month of growth (for grassland or perennial crops), senescence month, cultivation, fertilizer addition, irrigation, addition of organic matter (straw or manure), grazing, fire and erosion. Schedules with different sequences can be appended in *event100* and run in succession in the CENTURY model. For example, a series of historical farm practices such as breaking of the native sod in 1920, a wheat-fallow rotation with plow cultivation and straw removal until 1940, wheat-fallow with stubble-mulch management until 1980, followed by wheat-sorghum-fallow can be scheduled. The same code, with parameter values selected from crop options within the *crop.100* file, is now used for all crop and grassland systems. The original CENTURY wheat model predicted yields primarily as a linear function of soil water at planting plus growing season precipitation. The new crop production submodel uses the monthly potential production routines which had been previously implemented for grassland systems. Potential production is a function of a genetic maximum defined for that crop, and 0-1 scalars depending on soil temperature, moisture status and shading by existing vegetation. A new scaling factor has been added for crops growing from seedlings, reflecting the partial interception of light with less than a full canopy present. Root growth is proportional to potential shoot growth, but can be made a function of time since planting to reflect the dominance of root growth in seedling cereal crops or the initial dominance of shoot growth in root crops. As with previous versions of CENTURY, actual production is limited to that achievable with the currently available nutrient supply and nutrient uptake is constrained between upper and lower limits. However, the limits of nutrient content for shoot growth are now a function of accumulated potential production in order to reflect the changing nutrient content with plant age. A function to restrict nutrient availability in relation to root biomass has been added. An option for symbiotic nitrogen fixation has also been added to the model.

For grain crops a harvest index is calculated based on a genetic maximum and moisture stress in the two months prior to harvest. The crop harvest routine also allows for the harvest of roots, hay crops or straw removal after a grain crop. A revision of the decomposition submodel including an additional suite of pools for microbial biomass in surface litter is currently being implemented with the new version of CENTURY.

Fertiliser addition can either be fixed amounts in a fixed month or automatic according to the crop requirements. The automatic option can be set to maintain crop growth at a particular fraction of potential production with the minimum nutrient concentration, or to maintain maximum production with plant nutrient concentrations at a nominated level between the minimum and maximum for that growth stage.

Irrigation can be scheduled either as fixed amounts at designated times or automatically according to soil moisture status. Cultivation options allow for the transfer of defined fractions of shoots, roots, standing dead and surface litter into standing dead, surface and soil litter pools as is appropriate. Thus the model can simulate a variety of conventional cultivation methods, such as plowing or sweep tillage, thinning operations or herbicide

application.

Many bugs in the model have been identified and fixed. These include the timing and sequencing of calls in the model, the stochastic generation of precipitation, the temperature response curve of cool season crops, and the distribution of nutrient uptake between shoots and roots.

Jon D. Hanson, Detailed Annual Report

1. Problem Definition

Climate change has become a major concern among many scientists. Atmospheric CO_2 concentration has increased 25% in the past 70 years. At present rates of increase, CO_2 will reach a concentration twice that of pre-industrial times within the next 75 years. Concentration of other greenhouse gases (e.g., methane, nitrous oxide, and chlorofluorocarbon compounds) are also increasing. Escalating concentrations of these gases absorb thermal radiation which subsequently warms the earth's atmosphere. General Circulation Models (GCMs) of the atmosphere suggest the average global temperature will increase by as much as 3°C to 5°C as atmospheric CO_2 levels double. GCMs also predict an increased rate of circulation in the global hydrologic cycle, which could lead to increased precipitation. However, GCMs cannot reliably predict regional scale climate change, the vital information that is needed to estimate the potential impact of climate change on agricultural production.

As CO_2 increases, plant communities will change and species will populate areas that were previously inaccessible. Other changes that could possibly take place include modified rooting patterns, increased seed germination and plant establishment, and increased nitrogen fixation. These changes could have direct repercussions on the Conservation Reserve Program aimed at returning marginal cropland to rangeland. Thus, the ultimate effect on rangeland could end up being positive especially for areas presently considered too dry for contemporary crop production. However, higher production does not necessarily mean increased agricultural sustainability. On the contrary, production increases could lead to decreases of soil organic matter and subsequent degradation of the rangeland ecosystem. If these systems are to remain stable, care must be taken to monitor livestock production systems for excessive removal of soil organic matter.

The objectives are:

1. Assess the impacts of climate change on livestock and grassland production in the major producing regions of the United States and

2. Identify and evaluate adjustments in practices and government programs and policies that would facilitate adaptation to climate change.

2. Approach

A dual emphasis was used to conduct this project. We first set out to determine where

grazing is the most economically important. As a result, we developed what we call the Range Dependency Index (RDI). A map of the index shows how important range cattle production (cattle not sold from feedlots) is to many of the counties within the Great Plains and Northwest. In Nebraska, for example, the RDI reaches a high of 46%, i.e. 46% of the county's income is from the sale of unfed beef cattle.

Our second emphasis was on evaluating how climate change will potentially effect those regions of the United States that have a high dependency on grazing cattle. During this phase of the project, much time was spent on validating our simulation tool to make certain it performed well enough to answer these important questions. Simulations were conducted for areas of the U.S. with high RDI values. Eleven indicators were examined to determine the fate of grazing lands under four different climate change scenarios. The indicator variables included: peak standing crop, carbon to nitrogen ratio, water use efficiency, soil organic matter, soil inorganic nitrogen, intake of grazed forage, digestibility of the grazed diet, forage to supplement ratio, milk production, and cow and calf weights at weaning. The climate change scenarios were effective doubling of CO_2 (550 ppm) alone and changes in precipitation and temperature associated with an effective doubling of CO_2 as predicted by three general circulation models: Geophysical Fluid Dynamics Laboratory (GFDL), Goddard Institute for Space Studies (GISS), and the United Kingdom Meteorological Office (UKMO).

3. Findings and Interpretations

Doubling of CO_2 alone caused only slight increases of plant production, but when CO_2 doubling was coupled with changes in precipitation and temperature, plant production increased significantly. The most limiting factors on rangeland are moisture and available nitrogen. Thus as expected, moisture accounted for the greatest increases in plant production. Yet, wet/dry cycles have tremendous consequences on rangeland production. Normal, periodic drought is as important an issue as man induced global climate change when considering agriculture in arid and semiarid lands.

Generally, both plant and animal production responded positively to climate change for the northern latitudes. However, higher production did tend to reduce the soil organic matter, increasing the chance for system degradation. Sustainability of long-term agriculture is necessary for a stable agricultural economy within the United States. Therefore, we must consider not only short-term economic trends, but also long-term ecological stability. To safeguard rangeland, a system should be implemented for long-term monitoring of soil organic matter. Animal production was, however, severely hampered in the southern regions of this study. The primary cause was the direct effect of temperature on the animals and the indirect effect of temperature on forage quality. Management may, however, compensate for this problem by selecting other breeds of animals, particularly Bos indicus.

Six key points were inferred from these simulation experiments. Firstly, the climate change scenarios tended to predict an increased length of growing season. Grasslands rely mostly on spring moisture while summers are generally very dry. The GCMs seemed to accentuate this pattern and as a result the growing season was longer (by some 30 days). Subsequently, production increased, particularly in the spring and fall. Secondly,

animal production decreased for the California and Southern climate change scenarios. Reduced animal production occurred coincident with increased plant production because of decreases in soil inorganic nitrogen and concomitant decreases in forage quality. The availability of nitrogen in rangeland systems is a controlling factor and is closely related to the decomposition of soil organic nitrogen. Thirdly, livestock production tended to shift northward because of adverse conditions (primarily high temperatures) in the southern regions. Fourthly, climatic variance between years was slightly greater for the scenarios than for the nominal run. If the variance for yearly production does indeed increase, then uncertainty regarding plant growth increases thereby resulting in uncertainty in management decisions. Fifthly, management will be able to compensate for climate change. Management of livestock will ultimately guide animal performance. In bad years the manager must either sell livestock or feed them. If vegetation production is more variable, then stocking rates must be decreased to reduce risk and to insure good animal vigor. And finally, intensive management costs money. The more intense the management, the more the cost to the operator. Thus, even though the livestock may perform at similar levels, in the end, beef productions costs may increase.

4. Future Plans

Future studies should combine SPUR simulation and LANDSAT imagery for regional green biomass assessment. The technique should incorporate the best attributes of both tools. The following approach is one method that could be used to combine the two tools. LANDSAT imagery should be acquired at key periods throughout the growing season. The LANDSAT data could then be used to stratify the region into greenness strata. Meteorological sites capable of providing historical climatic information necessary to drive SPUR must then be located and climatic data obtained. SPUR simulation sites should be placed in as many different greenness strata as exist around each meteorological site. Soils occurring at each simulation site must be identified and hydrology and soil parameters determined from soil database information or soil samples. Historical grazing information must also be acquired for simulation sites that are grazed by livestock. Model warm-up should be accomplished by running the model for at least 18 to 20 years prior to the study period using historical climatic data and grazing information. SPUR predictions of green biomass and the corresponding average vegetation index value within each strata should be used to develop a calibration curve which relates green biomass estimates to vegetation index response. The calibration model and the average vegetation index values for each greenness strata could than be used to estimate green biomass amounts for all strata occurring within the region.

The success of SPUR simulation of green biomass production is dependent on proper parameterization of the model. The collection of soil samples, from which hydrology component parameters can be estimated, may improve the ability of the model to predict green biomass amounts at that location. Determining how best to initialize the model remains a problem. One approach to model initialization would be the collection of baseline information on the distribution of carbon and nitrogen in the various biotic and abiotic components of the ecosystem, however, it would be impractical to assume that enough information could be collected to characterize multiple sites. Running the model for 18 to 20 years prior to the study period appears to be necessary for model warm-up. Our inability to adequately characterize the complex spatial interactions that affect

biomass production and utilization suggest that SPUR should be run on an individual site within a grazing unit rather then attempting to simultaneously simulate multiple sites. Prediction errors will result from the lack of spatial connectivity, however, the errors will not be compounded by incorporating guesses of the sites preference and site limitation vectors for grazing distribution, as was the case in the current study.

Future studies designed to develop relationships between sample estimates of dried green biomass and LANDSAT derived vegetation indices should combine the data into areas of similar biological response. Strata can be developed by delineating various plant communities or by classifying a LANDSAT image into areas of similar spectral response. By stratifying the area, fewer samples are required to characterize each region. In addition, the averaging of multiple samples within each strata will reduce the affect of errors associated with sample point location and changes in soil brightness. The design of a stratified sampling scheme coupled with the use of global positioning devices should improve the distribution and location of sample points within the each strata.

Other research plans and direction include:

Continuing development of a spatial modelling tool called GRIDS (Geographically Referenced Information Delivery System), which is capable of accepting and outputting georeferenced data within a spatial framework. GRIDS will have the capability of integrating SPUR modelling output and remote sensing information within a geographic information system called GRASS (Geographical Resource Analysis Support System) and an image processing package called ERDAS (Earth Resources Data Analysis System). Combining spatial technology with system modelling will allow the simulation of system processes within a space/time framework.

Enhancing our understanding of plant/animal interface. This work is necessary if we wish to develop new and improved resource management strategies and influence policy concerning our national grazing lands.

Continuing analysis of field data in conjunction with remote imagery and simulation models. This will include the development of interfaces that allow for including ground data into simulation models and the subsequent filtering of the output to allow for real time simulations.

We have developed a range dependency index for the United States. The theory behind the index should be applicable to other agricultural groups, such as wheat and corn. We will work at developing such indices.

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PROGRESS REPORT

Agroecosystem Carbon Pools and Dynamics (AERL9101)

A collaborative project between Colorado State University
and Michigan State University

E. T. Elliott, K. H. Paustian, E. A. Paul and I. C. Burke
with
C. V. Cole, K. S. Pregitzer, G. P. Robertson and R.G. Woodmansee.

The conversion of native ecosystems to agricultural lands in the Great Plains and Corn Belt regions of the Central United States was perhaps the most extensive ecological disturbance known in North America during the past 150 years. A major consequence of this land conversion has been the substantial loss of organic matter from soils across the regions . In turn, these soil C losses have been a primary anthropogenic source of carbon dioxide, second only to fossil fuel combustion in contributing to historical increases of global CO_2 concentrations. Since soil carbon levels in most Great Plains and Corn Belt agricultural soils have been reduced to levels well below those existing prior to the establishment of agriculture, the potential exists for increasing present soil C levels, thereby providing a sink for atmospheric CO_2. At present there is considerable debate whether increases in atmospheric CO_2 concentrations and global warming will, independently, result in significant changes in soil C storage . While not discounting the importance of these factors, the potential for increasing soil C levels in agricultural soils may be more dependent on changes in agricultural management practices and land use changes.

The objective of the research supported on this project, which is now half way through the first year of three years of funding, is to develop credible data sets on the potential for agroecosystems of the Great Plains and Corn Belt to sequester carbon. To accomplish this we will: 1) review the national and international literature on the impact of driving variables, including management, on soil organic matter (SOM) and produce a document summarizing the results, 2) hold a workshop where the scientific cooperators of this project will present summarized data from their sites, which will be further integrated into a form that can be used to parameterize and validate SOM models and 3) sample the experiments represented by the cooperators to obtain a uniform characterization of soil organic matter pools and organic matter input useful for parameterizing and validating SOM models.

Considerable progress has been made towards meeting our first year objectives. We have provided detailed data from a Great Plains site (Sidney, NE) and a Corn Belt

site (Lexington, KY). We have also provided a pedon soil database we have developed that includes over 800 carefully chosen sites. This database has allowed us to determine the relative controls of climate, texture and management on SOM. Provision of these preliminary site and pedon databases should allow the modeling component of the EPA program to develop in concert with the data collection. Further augmenting this facilitation, we were awarded supplemental funding to assist EPA to develop and verify the Century model in collaboration with Aqua Terra Consultants. This parallel development of the program components will facilitate the needed feedback for the most beneficial scientific development.

We organized a workshop titled "Soil organic matter in temperate agroecosystems: driving variable controls across a site network" held at the Kellogg Biological Station, Hickory Corners, Michigan on February 18-21, 1992. The proceedings of this meeting will be published as a two volume hard covered book tentatively titled "Soil organic matter in agricultural systems I. Carbon pools and dynamics, II. Controls through land use and management in temperate agricultural systems" edited by E.A. Paul and C.V. Cole. The first volume will include the conceptual and literature review papers presented the first morning of the meeting plus others (see appendix) while the second volume will be a compilation of the site presentations (plus others) including appendices of collated data (see appendix for workshop presentations and participants). Ultimately, we will produce an electronic database of all sites to be used for validating and testing models and hypotheses relating to soil carbon dynamics and the potential for using new management practices for sequestering C from the atmosphere. Development of this database will partially meet our commitments to EPA but the information we compile can be applied, along with additional information, to solving other problems pertaining to terrestrial ecosystems.

Site sampling and analysis will be accomplished in years 2 and 3, the synthesis of which should, along with the literature review and workshop proceedings, serve as the benchmark work on soil organic matter pools and dynamics for years to come. Depth of sampling for SOM samples taken from each site will, pending workshop discussion, be 0-2.5 cm and from 2.5 cm to the bottom of the plow depth for the treatment with the deepest plow layer at each site. This choice of sampling depth will allow comparison of all treatments at a site because depth of mixing of soil will be equivalent. For sites with no plow treatments (no-till and rangeland) the second depth of sampling will be 2.5-20 cm. The last depth will be 20-50 cm. This sampling should include > 90% of SOM at all sites.

Choice of the suite of analyses that will be undertaken for each site is based upon our experience and the needs of EPA. We will analyze each sample for bulk density and soil texture as well as the soil organic matter parameters of total, particulate, active fraction (mineralizable) and microbial C and N.

APPENDIX

EPA Site Network Map

Table 1a. Original_Corn Belt sites and cooperators

Table 1b. Added Corn Belt sites and cooperators

Table 2a. Original Great Plains sites and cooperators

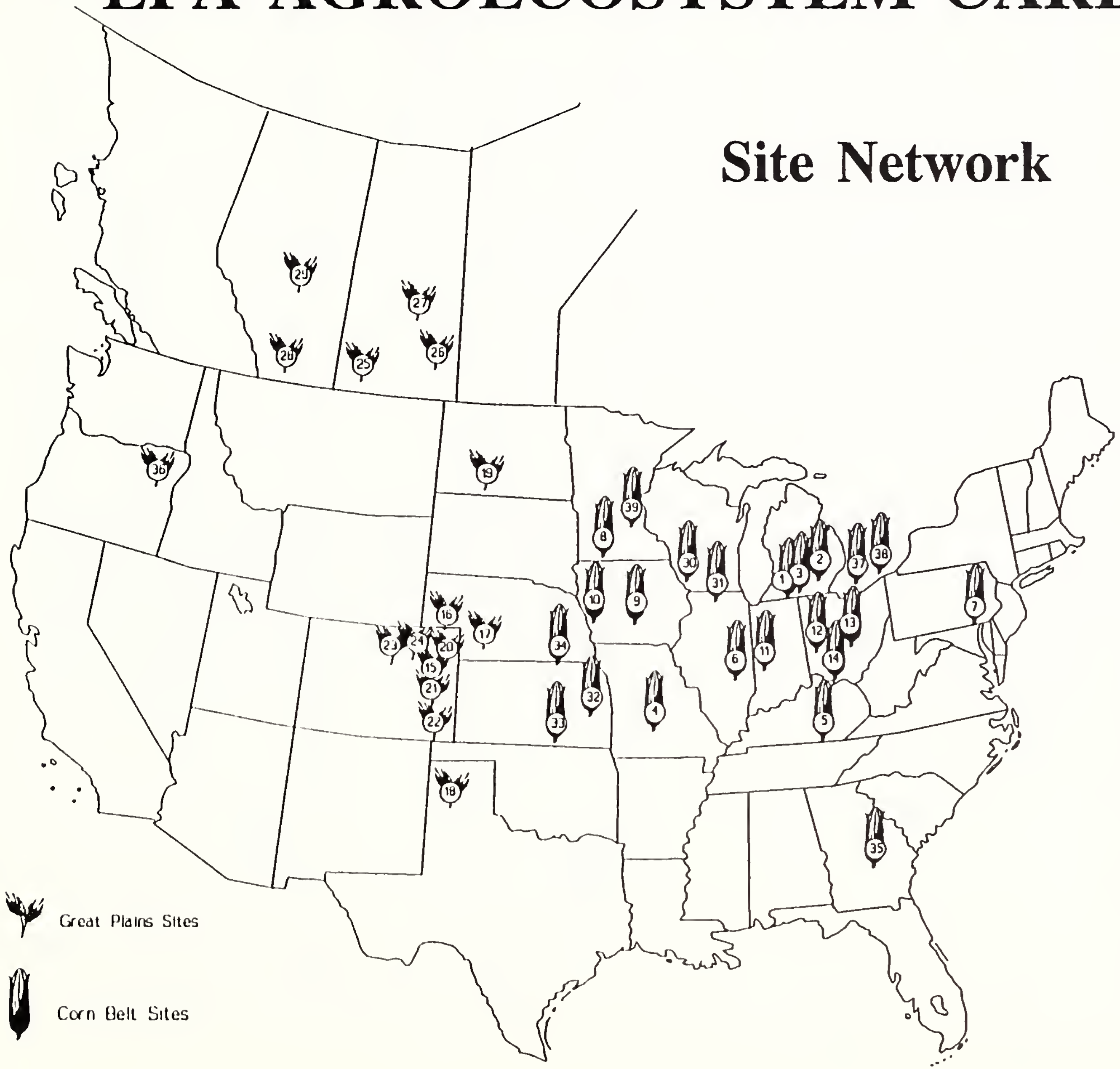
Table 2b. Added Great Plains sites and cooperators

Table 3. Added sites outside of the Great Plains and Corn Belt

Meeting Schedule - February 18-21, 1992

Planned Workshop Proceedings Publications

EPA AGROECOSYSTEM CARBON POOLS



1 KBS - LTER, Interactions, Forest - MSU
2 Saginaw Research Farm - MSU
3 MSU Old Soils Farm - MSU
4 Sanborn Plots - Univ. of Missouri
5 Kentucky Agric. Exp. Sta. - Univ. of Kentucky
6 Morrow Plots - Univ. of Illinois
7 Rodale
8 Koch Farm - VICM Plots - Univ. of Minnesota
9 Clarion-Webster Research Farm - ISU
10 Galua-Primghor Experiment Farm - ISU
11 LTSF, LTT & IPM Plots - Purdue Univ. /ARS
12 Hoytville - OSU
13 Wooster - OSU
14 Crosby - OSU
15 Central Great Plains - ARS - 2 sites
16 High Plains Lab - Univ. of Nebraska
17 W. Central Ext. Center - Univ. of Nebraska
18 Southern Great Plains - ARS - 2 sites
19 Northern Great Plains - ARS
20 Sterling - CSU/ARS
21 Burlington - CSU/ARS
22 Walsh - CSU/ARS
23 CPER - ARS, CSU - LTER
24 Pawnee National Grasslands - 13 sites
25 Swift Current - Ag Canada
26 Indian Head - Ag Canada
27 Melfort - Ag Canada
28 Lethbridge - Ag Canada
29 Breton - Univ. of Alberta
30 Lancaster - Univ. of Wisconsin
31 Darlington - Univ. of Wisconsin
32 Brown County - KSU
33 Riley County - KSU
34 Organic Conventional Mgt. - Univ. of Nebraska
35 Watkinsville - ARS
36 Pendleton - ARS
37 Delhi - Ag Canada
38 Elora - Univ. of Guelph
39 Rosemont - ARS

TABLE 1a. Original Corn Belt sites and cooperators

Name	Location	Period	Treatments	Contact Person and Affiliation
KBS/LTER	Hickory Corners, MI	1989-	Randomized block design (6 reps) w/ 8 cropping systems;	G. Robertson MSU
KBS/Interactions	Hickory Corners, MI	1986-	Previously cultivated soil: Continuous corn - 2 tillages, 2 fertilizer rates On virgin soil (never-tilled) No-till continuous corn with 0 N fertilizer vs. Native grass vegetation 6 treatments	G. Robertson MSU
KBS/Forest	Hickory Corners, MI	1942-	11 permanent points were randomly established in 1942, to serve as loci around which soil would be sampled over the next 50 years at 10 year intervals.	K. Pregitzer MSU
Saginaw Research Farm	Thomas Township, Saginaw County, Michigan	1972-	Crop rotation trials consisting of 4 systems X 3 rotation lengths, including corn, sugar beets, navy bean, oats, alfalfa	D. Christenson MSU
MSU Old Soils Farm	East Lansing, MI	1963- 1982	Split-block design with 3 replicates. Whole plots with 5 nutrient addition treatments (continuous corn) Never-tilled woodlot is located within 300 m	M. Vitosh MSU
Sanborn Plots	Columbia, MO	1888-	Treatment combinations consist of various crop rotation and fertility amendments. (treatments on 9 of the original 39 plots have been unchanged since 1988)	J. Brown G. Wagner G. Buyanovsky Univ. of Missouri
Kentucky Agricultural Experiment Station Farm	Lexington, KY	1970-	Split block design (4 reps per treatment) Continous corn 2 tillage treatments X 4 N fertilizer levels Control plots w/ bluegrass sod	W. Frye Univ. of Kentucky
Morrow Plots	Urbana, IL	1876-	3 rotations as main plots. Nutrient-additions in subplots of main plots: various combinations of manure, liming and NPK to subplots within each rotation.	R.Darmody T.Peck Univ. of Illinois
Rodale	Kutztown, PA	1981-	Randomized block with split-plots (rotation entry points as split-plot), 3 cropping systems	R. Janke S. Peters Rodale

Koch Farm - VICM Plots	Lamberton, MN	1989-	Randomized block with split-plot design, 2 rotations X 4 management levels The experiment is repeated on another area of the farm with a history of high fertilizer and pesticide inputs.	R. Crookston W. Nelson Univ. of Minnesota
Clarion-Webster Research Farm	Kanawha, IA	1954-	Randomized block with split-plot design 5 crop rotations (2 reps within year, all years in rotation as main plots) X 4 N fertilizer levels (split-plot)	J. Pesek ISU
Galua-Primghor Experiment Farm	Sutherland, IA	1957-	Randomized block with split-plot design 6 crop rotations (2 reps within year, all years in rotation as main plots) X 5 N fertilizer levels (split-plot)	J. Pesek ISU
Purdue LTSF Plots	West Lafayette, IN	1952-	Split-block design 21 combinations of P-K fertilization, applied to Corn-Soybean-Wheat-Corn (2 reps per treatment) 3 Residue levels 2 N levels (0 and 200 kg N per ha)	D. Stott D. Mengel R. Turco Purdue University
Purdue LTT Plots	West Lafayette, IN	1975-	Split block design (4 reps per treatment) Corn-Soybean rotation with 4 tillage treatments	D. Stott D. Mengel R. Turco Purdue University
Purdue IPM Plots	West Lafayette, IN	1981-	Split-plot design; whole plot=tillage & rotation, split-plot=weed mgmt. 3 rotations (each crop in each year for a total of 7 sequences)	D. Stott D. Mengel R. Turco Purdue University
Hoytville Plots	Wood County, OH	1963	Randomized block design 3 Tillage treatments X 3 rotations	W. Dick OSU
Wooster Plots	Wooster, OH	1962-	Randomized block design 3 Tillage treatments X 3 rotations	W. Dick OSU
Crosby Plots	South Charleston	1962-	Randomized block design Continuous corn X 3 Tillage treatments	W. Dick OSU

TABLE 1b. Added Corn Belt sites and cooperators

Name	**Location**	**Period**	**Treatments**	**Contact Person and Affiliation**
Darlington	Darlington, WI	1958-	Continuous corn with three N rates (plowed)	L. Bundy Univ. of Wisconsin
Lancaster	Lancaster, WI	1967-	Crop rotations by N rates (plowed)	L. Bundy Univ. of Wisconsin
NTRM Plots	Rosemont, MN	1980-	Three cultivation types and three N levels under continuous corn.	E. Klapp ARS
Organic Conventional Management	Mead, NE	1975-	Four crop rotations by fertilizer levels (including manure)	G. Lesoing J. Doran Univ. of Nebraska

TABLE 2a. Original Great Plains sites and cooperators

Name	Location	Period	Treatments	Contact Person and Affiliation
Long-Term Tillage Experiment	USDA-ARS Central Great Plains Research Station Akron, CO	1967-	4 tillage with 5 crop rotations	A. Halvorson ARS
Rotation x N Experiment	USDA-ARS Central Great Plains Research Station Akron, CO	1985-	No-tillage with 2 rotations and 5 N levels	A. Halvorson ARS
Long-Term Tillage Studies C&D	High Plains Agricultural Lab Sidney, NE	1970-	4 tillages with wheat/fallow rotation	D. Lyon Univ. of Nebraska
North Platte Cropping Systems	University of Nebraska West Central Research & Extension Center No. Platte, NE	1981-	Minimum tillage (irrigation) with 4 crop rotations	G. Hergert Univ. of Nebraska
Graded Terraces	USDA-ARS, Conservation & Production Research Lab, Bushland, TX	1958-	2 tillages with 3 crop rotations	B. Stewart O. Jones ARS
Mini-Bench Site	USDA-ARS, Southern Great Plains Bushland, TX	1982-	2 tillages with 4 crop rotations	B. Stewart O. Jones ARS
Tillage-Rotation Experiment	USDA-ARS, Northern Great Plains Research Laboratory Mandan, ND	1984-	3 tillage with 2 rotations and 3 fertilizer levels	A. Black D. Tanaka ARS
Dryland Agroecosystems in Eastern Colorado	Sterling, Stratton, & Walsh, CO	1985-	No-till with 3 sites and 5 rotation treatments (2 reps)	G. Peterson D. Westfall CSU
Central Plains Experimental Range - (USDA-ARS) Long-Term Ecological Research - (NSF)	Nunn, CO	1930- (ARS) 1981 - (LTER)	Several grazing intensities	J. Welsh W. Lauenroth ARS/CSU
Earthwatch Sites	Pawnee National Grasslands, Weld County, CO	1990	Secondary succession or no disturbance (13 paired native vs go-back sites). More to be established.	D. Coffin CSU

TABLE 2b. Added Great Plains sites and cooperators

Name	Location	Period	Treatments	Contact Person and Affiliation
Swift Current	Swift Current, Canada	1966-	Twelve crop rotations in all phases	C. Campbell R. Zentner Ag Canada
Indian Head	Indian Head, Canada	1958-	Eleven crop rotations from 1958 with three additional from 1968. All phases present.	G. Lafond Ag Canada
Melfort	Melfort, Canada	1957-	Eight crop rotations with all phases present	A Moulin L. Townley-Smith Ag Canada
Elora	Guelph, Canada	1965-	Three tillages under continuous corn	P. Voroney R. Beyaert Univ. of Guelph
Delhi	Guelph, Canada	1989-	Three rotations and two tillages. Constructed for long term use with stable isotope labelled plots.	P. Voroney R. Beyaert Univ. of Geulph
Dryland Rotations	Lethbridge, Canada	1951-	Three crop rotations with fertilizer treatments	H. Janzen Ag Canada
Restorative dryland rotations	Lethbridge, Canada	1951-	Thirteen treatments (rotations) including native grass	H. Janzen Ag Canada
Long-term no-till	Lethbridge, Canada	1967-	Two tillage and two crop rotations.	H. Janzen Ag Canada
Breton Plot	Edmonton, Canada	1939 1981-	Two long-term rotation treatments (64 years) and three rotation treatments on two soil types (11 yrs)	N. Juma Univ. of Alberta
Brown County	Brown County, Kansas	1974-	Three crop rotations and two tillages	J. Havlin KSU
Riley County	Riley County, Kansas	1975-	Three crop rotations and two tillage treatments	J. Havlin KSU

TABLE 3. Added sites outside of the Great Plains and Corn Belt

Name	Location	Period	Treatments	Contact Person and Affiliation
Watkinsville	Waskinsville, GA	1974 1982 -	Soybeans with conventional and no-till on similar soils	R. Bruce ARS
Pendleton	Pendleton, OR	1930, 1950, 1960-	Several crop rotations, tillage and ammendment treatments.	P. Rasmussen ARS

ANNUAL PROGRESS REPORT AND PLAN — CY 1991/92

Soil NO, N_2O, and CH_4 Exchange During N Transformations in Soil

G.L. Hutchinson

PROBLEM: There is increasing public and scientific concern regarding not only the prospect for global climate change, but also additional potential health and environmental effects of changing atmospheric trace gas concentrations. Gaseous N oxides, N_2O and NO_x ($NO + NO_2$), are directly or indirectly involved in "greenhouse warming" as well as the production and consumption of important atmospheric oxidants (e.g., ozone, hydroxyl) and the photochemical formation of nitric acid, which is the fastest growing component of acidic deposition. Methane is another radiatively-active trace gas with rapidly increasing atmospheric concentration; like NO_2, it is removed from the atmosphere principally via oxidation by hydroxyl, so NO_x and CH_4 compete with each other and with other pollutants for limited atmospheric oxidant. In addition to the important impacts of these gases on the chemistry of the atmosphere, soil NO_x exchange apparently comprises a sizable fraction of the unaccounted N losses typically observed in soil N balance sheets and also serves, like NH_3, as an agent for the transport and redistribution of N both within and among natural and agricultural ecosystems. Because microbial processes in soil is one of the principal sources of atmospheric N oxides, and represents both a source and sink for atmospheric CH_4, then it becomes important to determine the exchange rates of these gases across the soil-atmosphere boundary and, if appropriate, to develop control technologies (e.g., substitute land use schemes, alternative soil management practices, improved fertilizer formulations and application techniques, etc.).

APPROACH: During the last decade numerous measurements of soil N_2O emissions have enhanced understanding of the factors controlling this process and of the importance of soil emissions compared to other sources of this gas. My research focuses instead on NO_x exchange by soils and plants, for which relatively few measurements have been made, and investigates recently-advanced hypotheses concerning the relation of soil N transformation rates to CH_4 production and consumption in soil. Overall objectives of the research are (1) to characterize both the magnitude and direction of soil and foliar gaseous NO_x exchange in a variety of agronomically- and environmentally-important situations, (2) to determine the relation of NO_x to N_2O and CH_4 exchange rates in each situation, (3) to identify and characterize important controllers of the biotic an abiotic processes responsible for these exchanges, and (4) to assess the importance of the exchanges to crop productivity, to N use efficiency, to various environmental issues, and to the long-term behavior of natural and other low-N ecosystems. Procedures for laboratory soil incubation studies conducted to examine processes and pathways were summarized in a recent publication (Hutchinson and Andre, 1989). Methods for monitoring NO_x, N_2O, and CH_4 exchange at selected field sites and for field testing of preliminary laboratory findings have been summarized in previous reports.

CY 1991 ACCOMPLISHMENTS: Much of the past year was consumed by the following activities not directly related to my current research program:

(1) Training of a new biological science technician, who reported 30 December 1990.

(2) Preparation of three comprehensive review articles. The first (Pub. #5) was an invited analysis of chamber systems' use for measuring trace gas fluxes from soil presented at a SSSA special symposium (see Pub. #2), and the second (Pub. #3) summarized recent advances in our understanding of the controllers of NO and N_2O production, consumption, and transport in soil at both cellular and field/landscape scales. Probably most significant was Pub. #4, because of its completeness (110 pages), and because it represents a successful melding of biologists' and atmospheric chemists' viewpoints, which turned out to be a nontrivial undertaking.

(3) Summarization and publication of the last three years' results from cooperative studies with Prairie View A&M University (funded by NASA and a Specific Cooperative Agreement

using ARS money earmarked for cooperative research at HBCU's). Two of these articles (Pub. #6 and #7) are "in press", draft copies of two more (Pub. #9 and #10) are circulating among the authors, and Pub. #11 remains to be written. Publication #8, which summarizes the other five, has been submitted for inclusion in the book recording proceedings of the international conference where it was presented (see Pub. #1).

(4) Summarization and publication of cooperative studies with Dr. W.D. Guenzi conducted in the last year preceding his 1991 retirement. ARS peer reviews of Pub. #12 have been returned, and comments are being incorporated; preparation of Pub. #13 is in progress.

Despite heavy commitment to these training and writing activities, I was able to complete planned preliminary investigations to determine the feasibility of a more comprehensive field study of relations among soil NO, N_2O, and CH_4 exchange rates to be conducted in cooperation with personnel at the U.S. Central Great Plains Research Station on the Conservation Reserve Program (CRP) conversion plots located there. The rationale and planned approach to this research are summarized in the next section of this report. Briefly, this year's results showed that (1) soil emission of NO far exceeded that of N_2O on long-term grass plots, as well as wheat plots under both no-till and conventional tillage management; (2) soil management and tillage practices had substantial influence on N oxide evolution, with emission of both NO and N_2O varying in the order grass plots > no-till plots > conventional tillage plots, (3) short-term nitrifier activity measured in fresh soil samples appeared to integrate the dependence of NO (but not N_2O) emissions on soil temperature and water content, and (4) the soil's NO emission rate appeared to covary with its CH_4 uptake rate, suggesting that chemoautotrophic nitrifying microorganisms responsible for NO production in this soil may also contribute to its CH_4 sink strength. The last result should be considered especially tentative because of the marginal sensitivity and precision of our CH_4 analytical protocol, which have since been improved. In addition, we completed laboratory measurements to determine the dependence on relative humidity of the efficiency of the chromium trioxide convertor used to oxidize NO to NO_2 prior to its analysis using a luminol-based detector; these data will be included in Pub. #14.

CY 1992 PLANS: Short-term soil emission of NO_x (usually >90% NO) has recently been measured from several different ecosystem types under a variety of soil and climatic conditions around the world. Conspicuously absent from the literature, however, are comprehensive longer-term studies that yield tenable estimates of total annual NO evolution from any particular site. Further extrapolating existing data to assess the overall contribution of soil NO emissions to the global atmospheric NO_x budget is also confounded by the apparent existence of multiple biotic and abiotic sources of the gas. For example, elevated NO emission rates are sometimes associated with very wet or waterlogged soils and are stimulated by addition of NO_3^-, indicating that the source of NO is denitrification, but in drier situations NO emissions apparently arise primarily from chemoautotrophic nitrification, which is subject to an entirely different set of controllers. Because NO and N_2O are produced by the same microbial processes, there may exist a relationship between their evolution rates from soil that would permit using the extensive database of N_2O emission measurements to forecast NO emissions at similar sites, but the paucity of simultaneous field measurements of the two gas emission rates precludes describing any such relationship. Recent data suggest that the soil N transformations responsible for NO and N_2O production may also influence soils' rate of CH_4 uptake, but the relative contributions of specific microbial processes remain to be determined.

To overcome these limitations of existing data, we propose to (1) estimate total annual NO, N_2O, and CH_4 exchange from N-fertilized and unfertilized grass, no-till, and conventionally-tilled CRP plots at the Akron field station, (2) determine the relative contributions of nitrification, denitrification, and other processes (if they prove significant) to the measured exchange rates and (3) develop a process-level model that describes the contributions of each process to the measured exchange of NO, N_2O, and CH_4 in terms of easily-measured biological and geochemical parameters that have potential as predictors of the emission rates at other cultivated and grassland sites. Unlike existing models that attempt

(with limited success) to account for the large variability in soil C and N exchange over short distance and time scales, the focus of our modeling effort will be to develop a simple equation that facilitates assessing the spatially and temporally integrated contributions of various ecosystem types, climatic regions, soil groups, and/or management schemes to regional- and global-scale budgets of the three gases by integrating soil, climate, and land use parameters in a way that reflects only the differences in annual emission rates among sampling sites. In addition to the foregoing field effort, I will complete the writing activities outlined in the previous section, and William H. Anthony and I have planned laboratory soil incubation studies to determine the effect of oxygen availability on the relative contributions of nitrification and denitrification to soil NO, N_2O, and CH_4 exchange. The latter research will serve as Mr. Anthony's M.S. thesis in accordance with the terms of Specific Cooperative Agreement No. 58-5402-1-102.

PUBLICATIONS

1. Hutchinson, G.L., G.P. Livingston, and E.A. Brams. 1991. Nitric and nitrous oxide evolution from managed subtropical grassland. p. 18. *In* Abstr. 10th Int. Symp. on Environ. Biogeochem. (Abstract)
2. Hutchinson, G.L., and G.P. Livingston. 1991. Use of chamber systems to measure trace gas fluxes. p. 267. *In* Agron. Abstr. ASA, Madison, WI. (Abstract)
3. Hutchinson, G.L., and E.A. Davidson. 1992. Processes for production and consumption of gaseous nitrogen oxides in soil. *In* D.E. Rolston et al. (ed.) Agroecosystem Effects on Radiatively Important Trace Gases and Global Climate Change. SSSA Spec. Pub., SSSA, Madison, WI. (In press)
4. Williams, E.J., G.L. Hutchinson, and F.C. Fehsenfeld. 1992. NO and N_2O emissions from soils. Global Biogeochem. Cycles. (In ARS peer review)
5. Hutchinson, G.L., and G.P. Livingston. 1992. Use of chamber systems to measure trace gas fluxes. *In* D.E. Rolston et al. (ed.) Agroecosystem Effects on Radiatively Important Trace Gases and Global Climate Change. SSSA Spec. Pub., SSSA, Madison, WI. (In press)
6. Hutchinson, G.L. and E.A. Brams. 1992. NO vs. N_2O emissions from an NH_4^+-amended Bermuda grass pasture. J. Geophys. Res. (In press)
7. Hutchinson, G.L., W.D. Guenzi, and G.P. Livingston. 1992. Soil water controls on aerobic soil emission of gaseous N oxides. Soil Biol. Biochem. (In press)
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9. Brams, E.A., G.L. Hutchinson, and C. Nwambuonwo. 1992. Diel variability in N_2O emission from subtropical grass pastures. Plant and Soil. (First draft in author review)
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United States Department of Agriculture
Agricultural Research Service
Northern Plains Area
Crops Research Laboratory
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80526

12 February 1992

TO: Ron Follet

FROM: Jack A. Morgan JAM

CC: G.E. Schuman, Research Leader and J.R. Welsh, Director, NRRC

SUBJECT: Progress on Global Climate Change Research: 1991

In spring 1991, we concluded the third and last trip to the Duke Phytotron for photosynthetic and related measurements of blue grama and western wheatgrass grown under various CO_2/temperature regimes. Bill Hunt (systems ecologist, NREL, Col. State Univ.), my collaborator on this project, and I are writing two papers describing results from this research effort. My report will focus on the basic physiology of plant responses to CO_2 and temperature, and Hunt is developing a modeling paper. On 3 February, 1992, we submitted a proposal to the Competitive Grants Program of CSRS, again developing research problems that will allow the testing of hypotheses concerning plant responses to CO_2, and including a modeling component that will enable some worthwhile extrapolation of the data. For the modeling phase of these studies, we are using the Grassland Ecosystem Model, recently developed by Hunt (Hunt et al., 1991. Simulation model for the effects of climate change on temperate grassland ecosystems. Ecological Modeling 53:205-246).

In August, 1991, Dr. John Read arrived in Ft. Collins and began a two year position with me as a Research Associate studying responses of blue grama and western wheatgrass to CO_2 and temperature. We are investigating the biochemical causes of acclimation responses of these two grasses to CO_2 and temperature. The funding we received last summer gave Dr. Read at least a three-month head start on the project, and allowed us to develop a CO_2-control system for our growth chambers that otherwise may not have been possible. He is currently in the middle of a second run, growing the grasses under various CO_2/temperature regimes, periodically examining gas exchange of leaves, harvesting plants and roots, and storing lyophilized plant samples in a freezer for further carbohydrate and nitrogen analyses.

Publications: Morgan, J.A., H.W. Hunt, C.A. Monz, D.R. LeCain, and J.K. Detling. 1991. The effects of elevated CO_2 and climate change on photosynthetic response of blue grama and western wheatgrass. ESA Meetings, San Antonio, Texas (Abstract).

ASSESSING GLOBAL CHANGE

BIOGEOCHEMICAL DYNAMICS

1991 ANNUAL REPORT

Arvin R. Mosier & Kevin F. Bronson

Measurement of Trace Gas Fluxes (CH_4 & N_2O in Native and Agroecosystems and Development of Methods to Mitigate the Impact of Agriculture on these Fluxes

General Program

In cooperative efforts with Colorado State University, the Forest Service and other ARS personnel we began, in 1990, developing a network of sites within the Rocky Mountain and Great Plains area for long term (3-5 yr) monitoring of CH_4 and N_2O fluxes from a variety of ecosystems. These ecosystems include subalpine meadows, irrigated mountain meadows, the short grass steppe, dry land wheat, and irrigated agriculture. Within these locations we are intensively monitoring gas fluxes and looking at the physical, chemical and biological factors which influence gas flux. Within the short grass steppe we are looking at the influence of landscape and pasture management on gas fluxes from the aspect of the effect of land use changes on gas flux and spatial scaling to integrate larger areas. Long term data sets are not available and are needed to assess interannual variability. The data produced from these studies is being integrated with data collected from other studies during the past 14 years for N_2O to first develop process level models to describe CH_4 oxidation and N_2O production and secondly to incorporate the concepts developed into regional scale predictive models. Modeling efforts are conducted cooperatively with Colorado State University.

Efforts are underway to develop a transect of sites from Alaska to Puerto Rico to assess the variability of trace gas flux across the entire U.S. climatic gradient. Dr. Verlan Cochran in Fairbanks and yet to be identified cooperators in Puerto Rico will work with us on these studies.

Results

Three sets of sites were established in the Colorado shortgrass steppe during the spring of 1990. One set was established along a toposequence to determine the effect of landscape position, a second set was established in native and annually N-fertilized pastures and a third set was established in a pair of wheat fields cropped in alternating years (wheat-fallow system)

and in an adjacent grassland that was plowed last in 1939 and returned to "native grassland". Our data suggest that N fertilization in natural ecosystems increases N_2O emissions and decreases CH_4 uptake. These studies also indicate that recent changes in use or management of grasslands, such as cultivation, also decrease CH_4 uptake from the atmosphere. The soils appear to have a long term "memory" effect related to N fertilization and cultivation.

About 1.5 Tg of N_2O is emitted from N-fertilized agricultural soils each year. This is a small loss of fertilizer N but does amount to 10 to 20% of the annual global efflux of N_2O to the atmosphere. One means of limiting N_2O production in N-fertilized soils is to use nitrification inhibitors (NI). Because most commercially available nitrification inhibitors are not very effective we have worked with developing a new inhibitor, coated calcium carbide (CCC) which provides a slow _in situ_ release of acetylene. We conducted field studies in irrigated maize, dry seeded rice and irrigated winter wheat to determine the impact of CCC and commercially available NI on nitrification and N_2O emissions from urea-fertilized soils. Nitrous oxide emissions from maize field plots treated with CCC or nitrapyrin were reduced 71 and 41%, respectively, compared to urea fertilizer without NI. In irrigated winter wheat CCC and dicyandiamide decreased N_2O emission 45 and 53%, respectively during a 290 d period. In dry seeded rice, during the 3-4 weeks between seeding and fertilization and permanent flooding, CCC decreased N_2O emissions 73% while nitrapyrin increased N_2O production by 23% relative to soils treated with urea alone. These data suggest that NI's generally help decrease N-fertilizer derived N_2O emissions. There are instances, however, where this is not the case. Coated calcium carbide effectively decreased N_2O emissions in all three different cropping systems investigated.

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Rising Carbon Dioxide and Climate Change Effects on Rice Photosynthesis, Growth, and Yield

Plant Stress and Protection Research Unit, Gainesville, Florida
L.H. Allen, Jr. and many excellent colleagues

Work on methane evolution and mitigation during FY1991 was accomplished in the following two main categories.

1. Organization and preparation of a "methane database". Topics searched included methane (and nitrous oxide) efflux from soils, the biogeochemistry, biology, and ecology of methanogens, methane chemistry in the atmosphere, and methane in relationship to global climate change. Sources searched include Current Contents on Diskette, USDA Current Awareness Literature Search, Silver Platter, and hard copy abstracts (e.g., Bioabstracts, Chemabstracts).

2. Assembling, modifying, and constructing equipment for the quantification of methane emission from a paddy rice environment. Equipment required to measure methane (GCs, detectors, air sampling system) directly from a SPAR chamber system have been acquired and installed. The hardware and software for computer-managed data acquisition and analysis have been assembled, calibrated, and tested. Also, small chambers designed to capture methane emissions from a small subset of the SPAR paddy environment have been constructed. Redox probes for soil measurement have been constructed and tested. Measurements will begin in Spring 1992.

Other accomplishments include:

3. Construction of a new SPAR chamber system. This system with microprocessor controllers at each chamber and a host processor in a field laboratory has been designed and constructed for measurement of the effect of a range of CO_2 concentrations and temperature on rice photosynthesis transpiration, growth and yield, and methane emissions. Furthermore, the system was designed to control root-zone factors of paddy water, fertilizer, soil amendments, and other management practices. Control algorithms work very well, and hardware shakedown trials are underway. Tests show that average drybulb and dewpoint temperatures can be maintained within ± 0.2°C and ± 0.4°C, respectively, and CO_2 controlled within ± 8 ppm, of set points.

4. Effects of CO_2 on N_2 fixation by a genetically altered cyanobacterium. The cyanobacterium allows loss of ammonia, from nitrogen fixation, to the aquatic or paddy-water environment. Elevated CO_2 increased rice biomass and grain yield, and the total amount of plant nitrogen, which suggests that elevated CO_2 can increase nitrogen fixation by the genetically altered cyanobacterium.

5. The season-long effects and interactions of CO_2 concentration [CO_2] of 330 and 660 μmol mol^{-1} and nitrogen fertilizer rate (N) of 200, 100, and 0 kg N ha^{-1} on rice canopy gas exchange, growth and final grain yield were determined. Canopy net photosynthesis was increased while evapotranspiration was decreased by both [CO_2] enrichment and increasing N treatment. Both increasing [CO_2] and N resulted in increased tillering, biomass and grain yield. With increasing N from 0 to 200 kg N ha^{-1} grain yields increased from 6.0 to 8.1 and 7.9 to 10.1 metric tons per hectare for the 330 and 660 [CO_2] treatments, respectively. Increased grain yield resulted mainly from production of more grain-bearing panicles with both [CO_2] enrichment and increasing N.

FY1991 Report

Temporary Funds

ARS Global Change Research Program

Thomas Sinclair
Gainesville, FL

Funds were received to support four activities.

(1) Cooperative work with John Monteith. Professor Monteith originally accepted a proposal to work in Gainesville for three months in 1992 (Jan.-Mar.). However, he requested a delay of about one year in coming to the U.S. due to conflicting demands arising upon his return to the U.K. The funds for supporting his visit remain sequestered in a Specific Cooperative Agreement with the University of Florida.

(2) Stomata and photosynthetic responses to night temperature. Experiments were successfully completed in documenting the responses in leaf gas exchange following plant exposures to various night temperatures. The response curves were obtained for peanut, pangola grass, and bahia grass. Peanut was the most sensitive with night temperatures less than 13°C causing a decrease in the following day's photosynthetic activity while in the grasses temperatures less than 6°C were required. Two manuscripts are in preparation reporting this work.

(3) Computer purchase. A computer was purchased and is being heavily used by the ARS Research Associate who is analyzing the economic impact of global environment change.

(4) Simple model development. The simple spring wheat model was extended to simulate successfully winter wheat growth and yield. Only a few adjustments were required in the basic spring wheat model to account for the cold temperatures experienced by winter wheat. A manuscript has been drafted to report this work. Interaction continues with Paul Doraiswamy (ARS Remote Sensing Project) and Paul Cook (USDA, NASS) to evaluate the use of simple crop growth models to simulate regional crop yields and water use.

Effects of Nutrient Transport in Cropping Systems on Environmental Quality and Fertilizer Efficiency

Lowry A. Harper and Ronald R. Sharpe
Southern Piedmont Conservation Research Center, P.O. Box 555, Watkinsville, GA 30677

Four studies are currently in varying stages evaluating nitrogen (N) dynamics in cropping systems including soil, plant, and aerial transport. Management and N dynamics studies of a double-cropping system of clover and sorghum has shown that with proper timing, early senescence of the clover system can provide water savings without reducing total clover-produced N for succeeding crops. Clover N accumulation from fixation, ammonia absorption, and scavenged N provided about half of N requirements for summer forage growth. While a cool-season legume may not provide sufficient N for succeeding crops, it can provide a portion of the N requirements while scavenging and reducing leaching of N to the groundwater.

Preliminary results of a cooperative study in The Netherlands has shown immobilization rates of applied N under intensive management systems. Even with high N input, the cropping system rather quickly went into mild N stress after fertilizer application and absorbed atmospheric ammonia (NH_3) most of the growing season. Nitrous oxide (N_2O) evolution was seen during periods of high available N but absorption was observed during other periods.

A study is underway to determine the total N balance and the gaseous fluxes of carbon dioxide (CO_2), NH_3, N_2O, and water vapor from an irrigated corn cropping system in Nebraska. Data processing from the first year's study is in progress and preliminary results have shown evolution of NH_3 early in the season with NH_3 absorption and desorption later in the season. No correlation has yet been established for absorption and desorption with other crop or management factors. Data processing for N_2O and CO_2 is incomplete.

Nitrogen dynamics is being studied in a Georgia dairy-waste effluent application system using center-pivot irrigation. Continuous cropping is being used to utilize nutrients from the effluent. Nutrient transport will be studied in the soil-plant system and gaseous transport will be evaluated during application and throughout the cropping seasons including NH_3, CO_2, N_2O, and possibly methane (CH_4), carbon monoxide (CO), and carbonyl sulfide (COS).

MEETING SCHEDULE

SOIL ORGANIC MATTER IN TEMPERATE AGROECOSYSTEMS: DRIVING VARIABLE CONTROLS ACROSS A SITE NETWORK

FEBRUARY 18-21, 1992
W.K. Kellogg Biological Station
Hickory Corners, Michigan

Monday, February 17

pm - Arrival of participants

7:00 pm - Icebreaker (in Kellogg Manor House)

Tuesday, February 18

8:20-8:30 am	Introductory comments	Paustian and Elliott
8:30-8:45 am	Welcome to KBS by station director	Webber
8:45-9:30 am	Impacts of agriculture on soil organic matter in the U.S.	Flach, Barnwell, and Crosson
9:30-10:15 am	SOM and the driving variable-process-property paradigm.	Elliott and Cole
10:15-10:30 am	Break	
10:30-11:15 am	Management controls on SOM: an overview.	Paustian, Collins and Paul
11:15-12:00 am	Regional analysis of soil carbon: a tool for expanding the state of knowledge.	Burke and Parton
12:00-1:00 pm	Lunch	
1:00-1:20 pm	Scientific charge to the workshop	Paul and Cole
1:20-2:00 pm	A conservation tillage cropping system experiment in the N. Great Plains.	Black and Tanaka
2:00-2:40 pm	Effects of crop type, rotation and manuring on SOM in Sanborn field soils during 100 years of cultivation.	Brown, Buyanovsky and Wagner

2:40-3:00 pm	Break	
3:00-3:40 pm	Soil C dependence upon crop cultural variables in a thermic-udic regime.	Bruce and Langdale
4:00-5:30 pm	Tour of KBS-Long Term Ecological Research (LTER) site.	Paul and Robertson
6:00-7:00 pm	Dinner	
7:30-9:00 pm	Discussion of possible future network projects (eg. trace gas studies).	

Wednesday, February 19

8:20-9:00 am	Effect of rotation and cultural practices on SOM in Saskatchewan.	Campbell, Zentner, LaFond, Moulin & Townley-Smith
9:00-9:40 am	SOM in sugar-beet and drybean cropping systems in Michigan.	Christenson
9:40-10:20 am	Soil organic matter changes through time in the Morrow Plots.	Darmody and Peck
10:20-10:40 am	Break	
10:40-11:20 am	Continuous application of no-tillage and changes in organic matter-related soil properties in Ohio.	Dick
11:20-12:00 am	SOM under long-term no-till and conventional tillage in Kentucky.	Frye and Blevins
12:00-1:00 pm	Lunch	
1:00-1:40 pm	Long-term tillage-crop residue management study at Akron, Colorado.	Halvorson, Vigil, Peterson and Elliott
1:40-2:20 pm	SOM changes over two decades of winter wheat-fallow cropping in W. Nebraska.	Lyon, Brown and Monz
2:20-2:40 pm	Break	
2:40-3:20 pm	Implications for SOM of long-term rotation studies in Iowa.	Henning

3:20-4:00 pm	Effect of irrigation level on crop yield and residue under no-tillage in the Central Great Plains.	Hergert, Klocke, Nordquist, Wicks and Clark (presented by D. Lyon)
4:15-5:30 pm	Tour of KBS experimental forest and maple sugaring operation.	Pregitzer and Greg Kowalewski (KBS forester)
6:00-7:00 pm	Dinner	
7:30-9:00 pm	Continued discussion of site network projects including interactions with other networks.	

Thursday, February 20

8:20-9:00 am	Long-term effects of cropping practices on SOM in southern Alberta.	Janzen, Johnston, Carefoot and Lindwall
9:00-9:40 am	Management of dry-farmed southern High Plains soils for sustained productivity.	Jones, Unger and Stewart
9:40-10:20 am	Crop yield and SOM trends over 60 years in a Typic Cryoboralf at Breton, Alberta.	Juma, Robertson, McGill, Izaurralde, and Grant
10:20-10:40 am	Break	
10:40-11:20 am	Effects of residue and manure inputs on SOM in long-term plots in Michigan.	Vitosh and Lucas
11:20-12:00 am	Continuous corn and N fertilizer effects on soil C of high SOM mollisols, Lamberton, MN.	Huggins and Nelson
12:00-1:00 pm	Lunch	
1:00-1:40 pm	SOM in 1) livestock-, 2) legume cover crop-, and 3) fertilizer N-based field crop systems in S.E. Pennsylvania.	Peters and Janke

1:40-2:20 pm	SOM and biogeochemistry data from the Central Plains Experimental Range.	Burke, Woodmansee, Schimel, Milchunas, Elliott, Lauenroth and Forwood.
2:20-2:40 pm	Break	
2:40-3:20 pm	Management of dryland agroecosystems in the central Great Plains.	Peterson and Westfall
3:20-4:00 pm	Soil C under no-till and conventional tillage on two soils in Michigan.	Pierce
5:00-6:00 pm	Workshop Banquet	
6:00-6:20 pm	Coffee	
6:20-7:00 pm	Managing for nutrient containment and high production: implications for SOM in agricultural systems.	Harwood
7:00-7:40 pm	Sustainable ecosystems.	Woodmansee

Friday, February 21

8:20-9:00 am	Crop rotation, manure and agricultural chemical effects on crop yield and SOM over 16 years in E. Nebraska.	Lesoing
9:00-9:40 am	Changes in ecosystem C 46 years after establishing red pine (Pinus resinosa) on abandoned agricultural land.	Pregitzer
9:40-10:20 am	Long-term agricultural experiments at Pendleton, Oregon.	Rasmussen and Smiley
10:20-10:40 am	Break	
10:40-11:20 am	Effects of management on soil quality and productivity in long-term plots in Indiana.	Stott and Turco
11:20-12:00 am	Soil C after 19 years of no-tillage and conventional tillage of continuous corn, Ontario, Canada.	Winter and Voroney

12:00-1:00 pm	Lunch	
1:00-2:20 pm	Sampling procedures for cross-site comparisons of soil organic matter and soil properties.	General Discussion
2:20-2:40 pm	Break	
2:40-4:00 pm	Workgroup discussions of management effects on SOM and potential control of SOM in agricultural soils.	
4:00-4:30 pm	Workshop summary.	Elliott and Paustian

Saturday, February 22

(Activities for participants staying over Saturday)

Sunday, February 23

(Departure for remaining workshop participants)

Preliminary list of persons attending the workshop

Thomas O. Barnwell	(US EPA - Athens, GA)
Robert L. Blevins	(University of Kentucky)
James R. Brown	(University of Missouri-Columbia)
Russell Bruce	(USDA/ARS - Watkinsville, GA)
Gregory A. Buyanovsky	(University of Missouri-Columbia)
C.A. Campbell	(Agriculture Canada, Swift Current, Saskatchewan)
Dennis Child	(USDA/ARS - Beltsville, MD)
Donald R. Christenson	(Michigan State University)
C. Vern Cole	(USDA/ARS - Fort Collins, CO)
Harold P. Collins	(Michigan State University)
Robert G. Darmody	(University of Illinois)
Donn DeCoursey	(USDA/ARS - Fort Collins, CO)
Warren A. Dick	(The Ohio State University)
Tony Donigian	(Aqua-Terra Consultants, Mountain View, CA)
John W. Doran	(USDA/ARS - Lincoln, NE)
Edward T. Elliott	(Colorado State University)
Klaus Flach	(Herndon, VA)
Ernesto Franco	(Michigan State University)
Wilbur W. Frye	(University of Kentucky)
Richard R. Harwood	(Michigan State University)
Stanley H. Henning	(Iowa State University)
David R. Huggins	(University of Minnesota)
Henry H. Janzen	(Agriculture Canada - Lethbridge, Alberta)
O. Reggie Jones	(USDA/ARS - Bushland, TX)
Noorallah G. Juma	(University of Alberta)
Kim Kroll	(Rodale Institute Research Center, Kutztown, PA)
Steve Leavitt	(University of Arizona)
Gary W. Lesoing	(USDA/ARS - Mead, NE)
Changsheng Li	(The Bruce Company, Washington, DC)
Robert E. Lucas	(Michigan State University)
Drew Lyon	(University of Nebraska)
Chris Monz	(Colorado State University)
Lee Mulkey	(US EPA - Athens, GA)
Tim Parkin	(USDA/ARS - Ames, IA)
Avinash S. Patwardhan	(Aqua Terra Consultants, Mountain View, CA)
William J. Parton	(Colorado State University)
Eldor A. Paul	(Michigan State University)
Keith Paustian	(Michigan State University)
T.R. Peck	(University of Illinois)
Steve Peters	(Rodale Institute Research Center, Kutztown, PA)
Gary A. Peterson	(Colorado State University)
Francis J. Pierce	(Michigan State University)
Kurt S. Pregitzer	(Michigan State University)
Paul E. Rasmussen	(USDA/ARS - Pendleton, OR)
G. Philip Robertson	(Michigan State University)
Diane E. Stott	(USDA/ARS - West Lafayette, IN)
Donald Tanaka	(USDA/ARS - Mandan, ND)
Bernard Tinker	(Natural Environment Research Council of UK)
Merle Vigil	(USDA/ARS - Akron, CO)
Maurice L. Vitosh	(Michigan State University)
Patrick J. Webber	(Michigan State University)
Dwayne G. Westfall	(Colorado State University)
Julien Winter	(University of Guelph)
Robert G. Woodmansee	(Colorado State University)

Workshop proceedings volumes (titles and authorship subject to change).

Working title: SOIL ORGANIC MATTER IN AGRICULTURAL ECOSYSTEMS (Paul and Cole, eds.)

Volume I. Concepts and Methodologies

Volume II. A network of sites spanning the Great Plains and Corn Belt regions of the central United States.

ARS Global Climate Change Research Program
"Biogeochemical Dynamics"
1991 Research Progress- John W. Doran
USDA-ARS, Univ. of Nebraska, Lincoln, NE
February, 1992

Techniques were developed, in cooperation with Dr. Arvin Mosier, for measuring gaseous denitrification N losses from field soil using either acetylene blockage or ^{15}N isotopes. Total denitrification N and N_2O losses from the surface soil in irrigated corn in central Nebraska remained low throughout most of the growing season, generally ranging from 10 to 40 g N per heactare per day. During these sampling times soils were generally dry with less than 60% of the soil pore space being water-filled. Nitrous oxide was the major gaseous N product under these conditions, presumably a product of nitrification. When soils were wetted by irrigation or rainfall to greater than 70% water-filled pore space, denitrification losses ranged from 200 to 500 gN/ha/d with N_2 comprising 80 to 100% of denitrification gases measured. Soil respiration in the field ranged from 5 to 30 kgC/ha/d and was positively associated with soil water-filled pore space (WFPS).

A laboratory study was conducted to evaluate the effects of available C, soil nitrate, and soil WFPS on denitrification and the relative amounts of N_2O and N_2 produced in soils of varying texture and soil organic matter contents. Total N loss due to denitrification generally increased as soil texture became finer and WFPS exceeded 70%. However, denitrification rates at high nitrate concentrations were generally low without added C and increased with increasing available C (glucose). This research clearly demonstrated the futility of using an average N_2 to N_2O ratio to estimate total denitrification from N_2O field measurements because of the wide variation in this ratio due to the many environmental factors influencing denitrification and the relative production of N_2 and N_2O.

In a field lysimeter study, at the Management System Evaluation Area, N denitrification losses under simulated irrigation were shown to be largely controlled by levels of available soil C. Denitrification losses from the soil surface, over a four day period following irrigation with water containing 52 kg/ha nitrate-N, totaled 12.7 kgN/ha for irrigation treatments with added ethanol but only 1.7 kgN/ha where no ethanol was added.

Field measurements were made under irrigated corn at the MSEA site for water quality research in the Central Platte River Valley at Shelton Nebraska. Results for micro-meteorological flux measurements for ammonia, carbon dioxide, methane, and nitrous oxide in and above the crop canopy at this site in 1991 by Lowry Harper and associates are not available at the present time.

Summary of 1991 Research Progress for Global Change Program
(FY 1991 Funding)

Prepared by:
Joseph E. Miller, Research Leader
Air Quality-Plant Growth and Development
Raleigh, NC

Project numbers/titles:
6645-11000-002 (Response of Crop Species to Increasing UV-B, Tropospheric Ozone, and Carbon Dioxide)
6645-11000-003 (Global Climate: Effects of Chemical and Physical Changes in the Atmosphere on Crop Productivity)

Progress

In FY 1991, a large part of the unit's research activities in Global Change research centered around three primary lines of inquiry. These were the interactive effects of O_3 with CO_2, UV-B, and insect infestation.

The combined effects of elevated CO_2 and O_3 on crop growth and physiology were studied in greenhouse chambers with several crop species. Ozone caused injury, suppression of growth, and partial closure of stomates with white clover. Visible O_3 injury was less less at elevated CO_2 than at ambient CO_2. With soybean, suppression of biomass by O_3 was partially reversed by elevated CO_2 and elevated CO_2 increased nodule biomass as well as total plant biomass. Suppression of root/shoot ratios in mycorrhizal infected subterranean clover by O_3 was reversed by elevated CO_2. Controlled studies demonstrated that populations of spider mites on white clover increased faster in O_3-treated plants compared to control plants. The effects of elevated CO_2 on this relationship is being investigated.

A third year of study to measure the effects of increased UV-B radiation and O_3 on soybean showed that UV-B effects were minimal compared with O_3. Greenhouse experiments suggested that foliar injury and altered peroxidase activity could occur under high UV-B irradiance. Field experiments with more realistic plant growth conditions and UV-B/visible irradiances showed, however, that increased UV-B radiation had no consistent effect on foliar injury, chlorophyll content, net photosynthesis, chlorophyll fluorescence, antioxygenic enzyme activities or biomass accumulation. Biophysical studies of soybean leaves indicated that O_3, but not UV-B, affected tissue elasticity and specific leaf weight.
UV-B levels in excess of those resulting from a 25% depletion of stratospheric O_3 did not significantly affect soybean growth or yield. No significant UV-B x O_3 interactions were detected. In contrast, O_3 significantly affected all of these plant processes. Concentrations of UV-B absorbing compounds increased in UV-B and O_3 treated plants in the greenhouse and field. Better methods for measuring and modeling ground-level solar UV-B radiation continue to be developed.

(continued)

Increased cell wall autofluorescence and HPLC analysis suggest that O_3 induces deposition of phenolics in cell walls. Ozone effects on acidic peroxidase enzyme activity and tissue elasticity also reflect disturbance of cell wall metabolism and possibly indicate increased lignification. Phenylproanoid metabolism and other aspects of cell wall metabolism are being investigated to determine the mechanisms of O_3 effects on cell walls and growth.

Plant process models are being used to integrate data from field studies of O_3 and UV-B effects. This work is being done in cooperation with Dr. Sally Schneider, USDA-ARS, Oxford, NC. The GLYCIM model is being calibrated using control data from a 1990 open-top chamber experiment. Options will be explored to incorporate impacts of O_3 and CO_2 into the calibrated model.

In FY 1992 it is anticipated that field work on UV-B will be de-emphasized and that field work on CO_2 x O_3 interactions will be stressed. Work on a model of stomatal behavior for integrating effects of stress will continue. This model will be useful in estimation of CO_2 and O_3 fluxes under different scenarios of atmospheric stress.

Summary of 1991 Progress for Mechanistic Modeling of Global Change Effects on Crops (FY 1991 Temporary Funding)

Sally M. Schneider
Crops Research Laboratory
Oxford, NC

Joseph E. Miller
Air Quality-Plant Growth and Development
Raleigh, NC

Progress (9/91-1/92)

Growth data for the 1990 soybean study at Raleigh in open-top chambers under specific ozone and UV-B conditions has been has been converted to computer files. The documentation and source code for GLYCIM soybean growth model was obtained and S. Schneider has began familiarization with the model. A computer for use in the project has been purchased.

Since progress has been delayed by S. Schneider's participation in the ARS Systems Engineering class, the initial phases of the project will be extended through FY 1992 and possibly into FY 1993.

Plan of Work

Familiarization with the structure and content of GLYCIM will be completed and required data files will be constructed. Optimal soil conditions are assumed in this experiment since plants in the open-top chambers were grown in pots under near-optimum soil moisture and fertility conditions. Therefore, the components of GLYCIM associated with soil conditions will be eliminated from the model.
The modified GLYCIM model will be calibrated using control data from the 1990 open-top chamber experiment. Options will be explored to incorporate impact of ozone, elevated carbon dioxide, and UV-B into the calibrated, modified GLYCIM model. Additional data sets will be used to validate the model.

ANNUAL REPORT

SOIL CARBON IN NORTHERN PLAINS GRASSLANDS AND CONSERVATION SYSTEMS

MANDAN, ND

A.B. Frank and A.L. Black

A carbon-nitrogen analyzer was installed at Mandan on January 28, 1992. This instrument will enable us to conduct research on carbon sequestration and N status in grasslands and conservation tillage-cropping systems.

Research plans were developed in September 1991 to evaluate long-term grazing effects on carbon sequestration potential and soil carbon pools under Northern Plains grasslands. The initial emphasis will be placed on sampling grasslands that have a recorded 75-year history of grazing intensity, ungrazed areas, and CRP-type seeded grasslands. Specific treatments to be sampled include heavy grazed for 75 years, moderately grazed for 75 years, ungrazed for 75 years, and hayed, CRP-ungrazed and grazed pastures that were seeded to pure stands of crested wheatgrass, western wheatgrass, and smooth bromegrass in 1986. Soil sampling was delayed in October 1991 due to an unusually early snow storm and the subsequent early winter weather. Sampling will start in April 1992.

Soil samples by increment depth of 1.5 m were taken in the 65-acre cropping systems - conservation tillage study during the fall of 1991. The objectives of this work is to determine the effects of cropping sequence, tillage, and N applications over a seven-year period on soil carbon, nitrogen, and soil property changes. The treatments in this study provides a wide range in crop and residue production systems where changes in chemical/ physical soil properties and cycling of carbon, nitrogen, and phosphorus can be investigated.

TITLE: Micrometeorological Measurements of Carbon Dioxide Fluxes above Three C_4 Warm-Season Grass Ecosystems.

SUBMITTED BY: H.S. Mayeux, USDA, ARS.

OBJECTIVE: Determine whether land use and management practices affect carbon (C) sources and sinks by quantifying short-term carbon dioxide (CO_2) fluxes above three C_4 warm-season grass ecosystems which have different levels of disturbance.

INTRODUCTION:

Agriculture may be implicated in the 28% increase in atmospheric CO_2 observed since pre-industrial times. Extensive human disturbance of soil and vegetation, associated with land uses and management practices, may affect C sources and sinks. To increase our understanding of how global change can be affected by ecosystem disturbances, we propose research measuring C flux (F_c) over three C_4 warm-season grass ecosystems which have different land use and management practices imposed upon them.

Dramatic changes in the frequency and intensity of disturbance of extensive areas once dominated by perennial grasses due to conversion to agronomic fields or monoculture grass pastures have altered global C source/sink relationships. The general hypothesis of this research will be to assess whether the amount of C sequestered in a monoculture grassland ecosystem will be significant with respect to differences in soil organic carbon (SOC) between two ecosystems representing extremes of disturbance, namely a native grassland ecosystem and an agroecosystem.

METHODS:

F_c measurements will be made using the Bowen ratio/energy balance (BREB) method over an agroecosystem (a sorghum field), a newly-established monoculture grassland ecosystem (bermudagrass), and a native grassland ecosystem (tallgrass prairie). CO_2 fluxes will be used to determine, in conjunction with SOC analyses, the extent to which C source/sink relationships have been affected by land use and management.

About 2 ha of an existing 5 ha sorghum field will be planted with bermudagrass. F_c measurements will be made before, during, and after grass establishment. F_c differences between sorghum and bermudagrass will be used to quantify the amount of C sequestered. The tallgrass prairie is ca. 4 ha and has never been disturbed. It is representative of F_c and SOC for a natural ecosystem, and reflects equilibrium conditions for both of these terms.

BREB measurements will be made simultaneously over the three ecosystems for 3-5 weeks at a time about every 2 months, with the frequency and duration of measurements both being greater during the growing season. Data for periods between measurements will be linearly interpolated for calculation of annual fluxes.

The F_c is a flux above the surface and can be defined as follows: $F_c = gP_s - R_c - R_s - R_r$, where gP_s is gross photosynthesis, and R_c, R_s, and R_r are crop, soil, and root respiration, respectively. F_c

differences will reflect differences in gP_s, R_c, R_s, and/or R_r. Carbon content of aboveground and root biomasses will be sampled periodically and summed to estimate gP_s-R_c-R_r. This value, along with calculations of R_s from soil temperature and water content measurements, will be used as an independent measurement of short-term and annual F_c for comparison with BREB measurements. SOC will be measured on soil cores taken during the fall of each year.

DISCUSSION:

A hypothesized pattern of annual F_c (see below) shows tallgrass prairie $F_c=0$ because it is in a steady-state condition with respect to SOC and standing crop. Sorghum F_c is < 0 due to oxidation associated with tillage and other management practices and because a portion of the C is harvested. Sorghum approaches $F_c=0$ with time. Bermudagrass is a large C sink during the first year and remains a sink for an unknown number of years until it, also, reaches an equilibrium value and $F_c=0$.

Annual bermudagrass F_c during the first year of conversion (i.e., X_1 g C m^{-2}) will be compared with the SOC difference between the tallgrass prairie and sorghum (i.e., Y g C m^{-2} = $SOC_{tallgrass}$- $SOC_{sorghum}$). From this, the percentage of Y sequestered in bermudagrass in year 1 will be calculated from $100*(Y-X_1)/Y$ and be used to identify land use and land management effects and to evaluate the hypothesis. A similar calculation will be made in year 2.

Monthly F_c, critical for interpreting intra-annual disturbances, is shown below for year 1. For each ecosystem, the integrated area, relative to $F_c=0$, of the monthly curve is equal to the annual data point for year 1. All ecosystems are expected to be C sinks in the growing season. Daily and hourly F_c data would assist interpreting short-term phenomena.

SIGNIFICANCE:

This research will link long-term SOC measurements with short-term micrometeorological F_c measurements to provide insight on the mechanisms and seasonal dynamics of C fluxes, sinks, and sources in three ecosystems with different levels of disturbance.